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RESEARCH ARTICLE

DEVELOPMENT OF A STATISTICAL MODEL PREDICTING RICE PRODUCTION BY RAIN PRECIPITATION INTENSITY AND WATER HARVESTING

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ABSTRACT

Global climate change combined with high rain intensity variation can have detrimental effects on the yield of crop plants such as rice especially in north of Côte d'Ivoire where rice production meanly depend on the wetland cultivation system. Here we developed a multiple linear regression (MLR) statistical model to appreciate the mathematical relationship between rain precipitation intensity (rainfall intensity), water harvesting (rainfall water management) and rice production evaluating the impact of global climate change on the rice yield in north of Côte d'Ivoire. The present analysis showed that the production of rice in this area of the world relatively depend on both rainfall and rainfall water management. However, the developed multiple linear regression (MLR) model predicted that a decent management of the rainfall water (water harvesting) can improve the production of rice.

Key words:

Multiple Linear Regression (MLR), Rice Yield, Rain Precipitation, Water Harvesting.

INTRODUCTION

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population. It has been estimated that half the world's population subsists wholly or partially on rice. Since a large portion of maize crops are grown for purposes other than human consumption, rice is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by humans (Smith Bruce D., 1998).The food security of more than half the world population depends on the aptitude of the world to supply and distribute rice. Rice supply depends on global rice production, while its distribution depends on the distance from production sites to consumers' residences as well as on transportation systems and facilities (Nguyen N. V., 2004). Studies suggest that the temperature increases, rising seas and changes in rainfall patterns and distribution expected as a result of global climate change could lead to substantial modifications in land and water resources for rice production as well as in the productivity of rice crops grown in different parts of the world (Nguyen N. V., 2004). However, a report recommended that the greatest temperature increase could be expected in agricultural land in low latitude tropical regions (Rosenzweig and Iglesias, 1994). Darwin *et al*.(2005) estimated that the amount of land classified as primary land class for rice, tropical maize, sugarcane and rubber in tropical areas would decline by between 18.4 and 51 percent during the next century due to global warming. On the other hand, it is possible that the land and water resources for rice production in some regions of the world increase with global climate changes (Darwin *et al*., 2005).This circumstances reflect goodly the situation in the north of Côte d'Ivoire were traditional hand methods of cultivating and harvesting rice are still accomplished. In fact in this region of the world, the dam of Natiokobadara (Department of Korhogo in north of Côte d'Ivoire) has been built since 40 years to overcome global climate change negative impact on rice production and to improve its production. Nowadays, the water in this dam is insufficient to resupply family rice agriculture (Silué and Dago, 2014). Moreover, Silué and Dago (2014) showed that during the last 7 years, the former lost around 77% of its total volume. This phenomena could be due to both extreme temperature in the north of Côte d'Ivoire (in comparison to the south region) and

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hexogen factors (i.e. carelessness of dam due to several years of political turmoil ended with a brief civil war in 2011). Rice production and rain intensity during the same period go down to 18 and 11 percent respectively (Silué and Dago, 2014). Moreover, extreme temperatures whether low or high cause injury to the rice plant. In tropical regions, high temperatures are a constraint to rice production. Studies on rice productivity under global warming also suggest that the productivity of rice and other tropical crops will decrease as global temperature increases. Mohamed *et al*. (2002) estimated that by 2005, climate change in Niger could lower yields of millet by 13 percent, groundnut by between 11 and 25 percent and cowpea by 30 percent. Nonetheless, upland rice cultivation, especially in sub-Saharan Africa, is done under slash-and-burn shifting cultivation. Under this system the vegetation in a forest land area is cleared and burnt and the area is then cultivated to upland rice for 1 to 2 years before the farmers move to new areas. Farmers return to a previously cleared area only several years later to repeat the same process of cutting and burning of the cover vegetation. Upland rice production in sub-Saharan Africa is a major cause of deforestation and desertification. However, tropical sub-Saharan Africa has a total of 24 million ha of wetlands which are suitable for rice production (Andriesse, 1986). The development of wetland rice in sub-Saharan Africa would markedly reduce the deforestation which currently results from upland rice cultivation. Furthermore, methods of rice growing differ greatly in different localities, but in most Asian and African countries the traditional hand methods of cultivating and harvesting rice are still practiced. In this context the present study aim to establish a relationship between the rate of rice production in the north of Côte d'Ivoire(a sub Saharan Africa reality) and rainfall intensity and water harvesting (rainfall water management); where rice cultivation meanly depend on wetland practices. For this purpose, we developed a multiple linear regression (MLR) statistical model by using several functions of R statistical software package (Weisberg, S. 1985; R Core Team, 2013).

MATERIALS AND METHODS

Description of the Experimental Sites (Irrigation Dam of Natiokobadara)

The irrigation Dam of Natiokobadara was built in 1972 by the "Motoragri_1" to help rice production in the dense area of Korhogo (north of Côte d'Ivoire). It locates at longitude 5 ° 37 ' and latitude 9 ° 29' (Silué and Dago, 2014). It belongs to Bandamariver basin with a catchment area of 13.65 km^2. The annual average rainfall (rain precipitation) is around 1400mm. The irrigable area is 250 hectares, spread over approximately 9km. Previous study evaluated the change in water level of the above mentioned irrigation dam, by taking images from Google Earth (Silué and Dago, 2014). These analyses have been performed in 2007, 2009, 2011 and 2013. The images of the first two years (2007 and 2009) are taken into wet period, while those of the other's two (2011 and 2013) have been taken in the dry season (Silué and Dago, 2014). In the present work we emphasized the relationship between rice production, rainfall (rain precipitation intensity) and water harvesting (management of rainfall water by means of the Dam of Natiokobadara) parameters emerging a multiple linear regression (MLR) statistical model with the aim to predict the production of rice applying the wetland practice inrice cultivation.

Collection of Rice yield, Rainfall and Water Harvesting (management of rainfall water) Parameters Data

The collection of the present analyzed data has been described by Silué and Dago (2014). Briefly, and as previously reported, the change in water level have been performed by taking images from Google Earth. The calculation of the surfaces of water was automatically generated from the module Calculate Area present in the utilities of the Spatial Statistics Tools extension ArcToolbox. The operation was used to evaluate the surface of the water of the Dam for each year of study (Silué and Dago, 2014). Moreover, this study uses a diachronic approach based on photo- interpretation of images. Next a visit in rice farm associated to a survey analysis with the collaboration of rice farmers allowed to obtaina complement information. In order to improve the quality of the analysis we calculated both overall and annual average growth rate of each analyzed parameter (Silué and Dago, 2014). However, rice production data from 2007 to 2013 in the region of Natiokobadara has been provided by "Coopérative Womiengnondes riziculteurs de la Région des Savanes en Mars 2014", while the fluctuation data regarding the rainfall around the studied site have been delivered by "Sodexam: Sociétéd' exploitation et de Développement aéroportuaire, aéronautique et météorologique and Coic:compagnie ivoirienne de cotton" (Silué and Dago, 2014).

R Software for Statistical Analysis and Development of Multiple Linear Regression Model

Before going into the actual statistical modelling and analysis of a data set, it is often useful to make some simple characterizations of the data in terms of summary statistics and graphics. In descriptive statistic pie-chart and bar-chart diagram are useful graphic for complex data summarization and representation.

- In the present analysis R software "*Piechart*" and "*Barplot*" functions have been used to summarize and analyze rice yield (rate of rice production), rainfall intensity (rain precipitation intensity) and water harvesting (rainfall water management through monitoring of the Dam) parameters relationship.
- One sample student test (one sample "*t.test*" function in R package) (P. Dalgaard, 2008) has been performed to highpoint the change inside each analyzed parameters (rice production, rainfall and water harvesting) and between each season (dry and wet seasons).
- Principal Component Analysis (PCA analysis) script with the goal to establish the relationship between the three analyzed parameters as developed in Dago *et al.* 2015 has been used and adjusted for the present analysis.

Next we developed a statistical model analysis based on a multiple linear regression (MLR) equation by using the linear model "*lm*" function of R package (Weisberg, S. 1985) assessing the mathematical relationship between rice yield (rice production) considered as the response parameter (Y) and two predictors or explanatory parameters; named rainfall (rain precipitation intensity) (X_1) and water harvesting (management of rainfall water by monitoring the Dam water) (X_2).

- Regression is a tool that allows researchers to model the relationship between a response variable Y and a number of explanatory variable, usually denoted X_k (Ali Hussein Al-Marshadi, 2014). In general form, the statistical model of Multiple Linear Regressions (MLRs) is:$Y_i = \beta_0 + \sum_{k=1}^{p-1} \beta_k X_{ik} + \varepsilon_i$(E1). Where:$\beta_0$, $\beta_1 \ldots \beta_{p-1}$ represent the unknown parameters;$X_{i1} \ldots X_{i,\ p-1}$ the explanatory variables and ε_i the residual value of the developed MLR equation.

Data Normalization Process

In statistics and applications of statistics, normalization can have a range of meanings (Dodge Y, 2003). In the simplest cases, normalization of ratings means adjusting values measured on different scales to a notionally common scale, often prior to averaging. In more complicated cases, normalization may refer to more sophisticated adjustments where the intention is to bring the entire probability distributions of adjusted values into alignment. In the case of normalization of scores in educational assessment, there may be an intention to align distributions to a normal distribution. In another usage in statistics, normalization refers to the creation of shifted and scaled versions of statistics, where the intention is that these normalized values allow the comparison of corresponding normalized values for different datasets in a way that eliminates the effects of certain gross influences, as in an anomaly time series. Here we apply logarithm transformation on each rice production, rainfall intensity and water harvesting analyzed parameters with the aim to allow comparison and establish a relationship among these parameters developing a MLR model.

RESULTS

Descriptive statistic of Rice Production, Rain Precipitation Intensity and Water Harvesting Parameters from year 2007 to year 2013

Descriptive statistics are used to describe the basic features of the data in a study. They provide simple summaries about the sample and the measures. Together with simple graphics analysis, they form the basis of virtually every quantitative analysis of data. Here, we summarized features data of rice production, rain precipitation intensity and water harvesting parameters by performing a descriptive statistical analysis as reported in table 1and figure 1. In data mining and statistical data analysis, data need to be prepared before models can be built or algorithms can be used. In this context, preparing the data means transforming them prior to the analysis. Then, the present analyzed data have been normalized applying logarithm transformation with the aim to make straightforward the relationship analysis between rice production, rain precipitation intensity (rainfall)and water harvesting (management of rainfall water) analyzed parameters, which result expressed in different units (heterogeneous data) (Table 1). Moreover, table 1showed that data normalization process drastically reduced the standard deviation value among the features data of each analyzed parameters (p-value 2.159e-06; Fisher test estimating variance difference). In addition, this analysis revealed that rainfall parameter(normalized data) exhibited the lowest standard deviation with respect to the others analyzed parameters (Table 1 and Fig. 1) suggesting a relative constant variation of rain intensity in the north region of Cote d'Ivoire from year 2007 to year 2013.

Table 1 Summary of descriptive statistic of row and normalized data of the features of the three analyzed parameters

	Water Harvesting (ha)	Rice Production (T)	Rainfall Intensity (mm)
Mean_value_Row_Data	37	9.44	1254.13
Standard_Deviation_Row_Data	**20.7**	**3.62**	**187.19**
Mean_Normalized_Value	1.51	0.95	3.1
Standard_Deviation_Normalized_Value	**0.28**	**0.16**	**0.07**
Log10_Maximum_Value	1.79	1.15	3.15
Log10_Minimum_Value	1.15	0.78	3

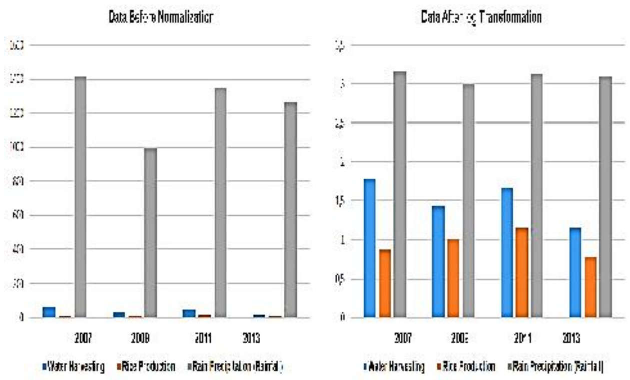

Figure 1 Water harvesting, Rice Production and Rain Precipitation un-normalized (row) and normalized data representation.

Seasons Impact Evaluating the Change in Rice Production, Rain Precipitation Intensity and Water Harvesting

For presentation purposes, it may be desirable to display a graph rather than a table of counts or percentages. Piecharts from statistical R package are traditionally frowned upon by statisticians because they are so often used to make trivial data look impressive and are difficult to decode for the human mind. Here the Pie charts representation for rice production, rain precipitation intensity (rainfall) and water harvesting (rainfall water management by Dam water monitoring) parameters, evidenced a strong heterogeneity between these three analyzed parameters during analyzed period(Fig. 2).Moreover, these results revealed that year 2011 resulted the less heterogeneous (p-value < 0.1) with respect to the others (2007, 2009 and 2013), while 2013 year exhibited the highest heterogeneity analyzing the feature data of the three considered parameters (p-value > 0.1).Then, while the different analyzed parameters under the dry season (2011 and 2013) exhibiteda significant difference among themselves (high heterogeneity), those analyzed for the period of wet season (2007 and 2009) displayed a weak variability among themselves(0.1< p-value ≤0.1). Next, we performed a statistical analysis based on a student test, showing that season discriminate (dry season: 2011-2013 and wet season: 2007-2009) was not an adequate parameter to explain the heterogeneity phenomena observed between the three analyzed parameters (rice production, water harvesting and rainfall intensity). Taking together, the present statistical analysis highlight a high heterogeneity between rice yield, rainfall intensity and water harvesting parameters for the analyzed period, suggesting the difficulty to infer a relationship, between these three parameters predicting rice production.

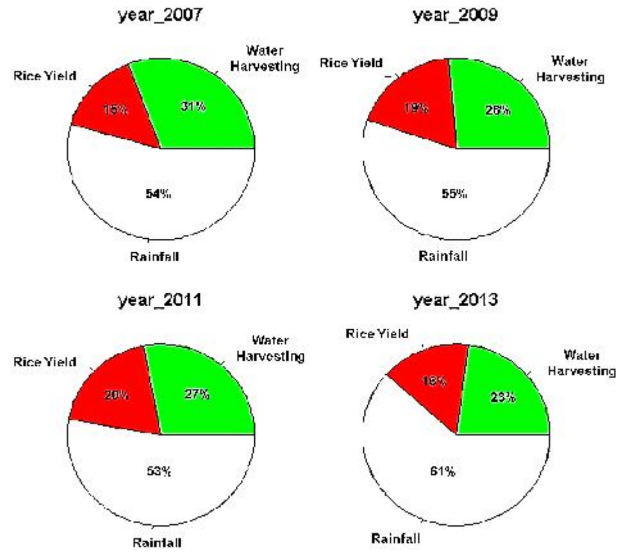

Figure 2 Graphical representation (pie chart statistic) of rice production, water harvesting and rain precipitation intensity percentage for each considered year (2007, 2009, 2011 and 2013).

Statistical Student Test Evaluating the Variableness in Rice Yield, Water Harvesting and Rain Precipitation Intensity Parameters

Next, we test the attitudes of the three analyzed parameters by a statistical analysis based on the one sample student test (one sample "*t.test* "function of R software). The present t test based on an assumption that data come from the normal distribution. In the one-sample case we thus have data $x_1, \ldots, x_n$(feature data of the three analyzed parameters for each considered years) assumed to be independent realizations of random variables with distribution $N(\mu, s^2)$, which denotes the normal distribution with mean $\mu$and variance s^2, and we wish to test the null hypothesis that $\mu = \mu_0$. In this context, the statistical student test analysis for the rice yield parameter exhibited normal variability or data distribution (p-value =0.01).

The same analysis suggested a weak variation in rain precipitation intensity parameter (p-value = 0.0008) with respect to those of water harvesting (p-value = 0.04) as above showed (see also Fig. 3). Compared with bothrain precipitation intensity (rainfall) and water harvesting parameter (management of rainfall water by monitoring the Dam of Natiokobadara), rice yield parameter exhibits a normal variability distribution (Fig. 3). Taking together, these results suggest that during the analyzed period, water harvesting resulted the less stable parameter in comparison to the other's evidencing a bad management of rainfall water during this period (wicked monitoring of the water of the dam of Natiokobadara).

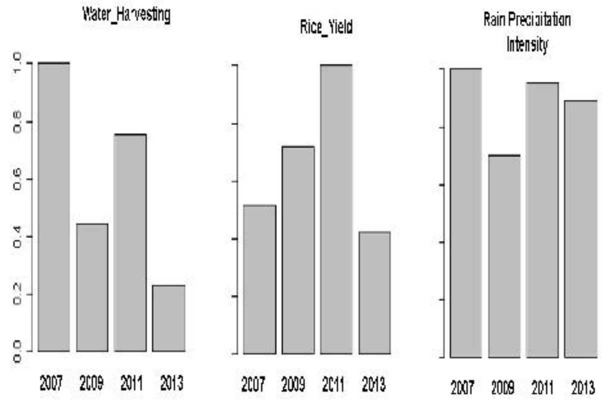

Figure 3 Barplot estimating intersect variation of the water harvesting, rainfall intensity and rice production parameters during the four considered years (2007, 2009, 2011 and 2013).

Estimation of the Relationship between Rice Yield, Water Harvesting and Rain Precipitation by Principal Component Analysis (PCA)

We are interested to establish a relationship between rice production and water harvesting (rainfall water management) and rain precipitation intensity (rainfall) from year 2007 to 2013.We first performed a spearman correlation analysis among the normalized value of these three analyzed parameters. The Rho valuesobtained between the three analyzed parameters performing the Spearman correlation analysis are 0.80, 0.40and 0.00 (p-value > 0.1). In fact, the highest correlation value has been obtained between rainfall and water harvesting parameters, while the estimated correlation between rice yield and rainfall parameters is low and statistically insignificant. Next, we accomplished a Principal Components Analysis (PCA), identifying patterns in data, and expressing the data in such a way as to highlight a relationship between rice production, water harvesting (rainfall water management) and rain precipitation intensity (rainfall intensity) parameters. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing data. The other main advantage of PCA is that once you have found these patterns in the data, and you compress the data, by reducing the number of dimensions, without much loss of information.

The present PCA analysis evaluating the pattern in data of our three analyzed parameters (rice production, water harvesting and rain precipitation intensity) highlighted a relative discrete link between water harvesting (rainfall water management) and rain precipitation intensity (Fig. 4).

Moreover, this analysis also suggested that the water harvesting or a good management of rainfall water from rain precipitation, could better predict and improved the production of rice; even if these two parameters (water harvesting and rice yield) are not strongly associated (Fig. 4). Taking together, these results propose that a good management of the water from rainfall (water harvesting) may contribute to the improvement of rice production in the north of Côte d'Ivoire.

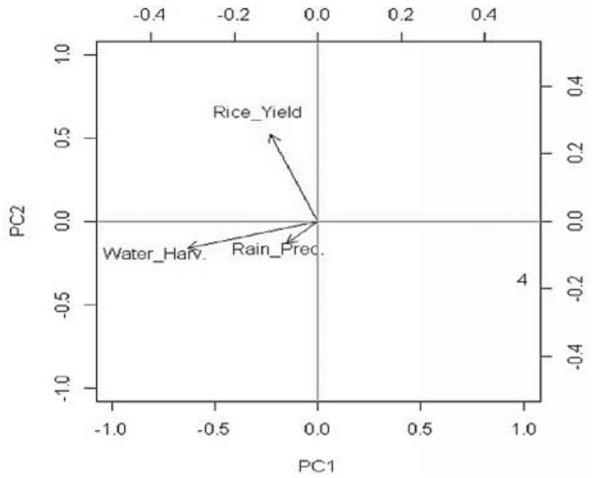

Figure 4 PCA analysis assessing the agreement and/or disagreement and/or relationship between rice production and water harvesting (rainfall water management) and rain precipitation intensity.

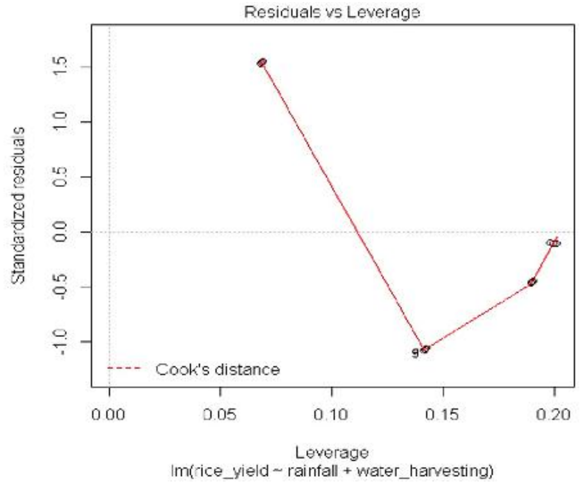

Figure 5 Assessment of the residual value of the developed multiple linear regression (LMR) model by a simulation analysis.

Multiple Linear Regression Analysis Predicting Rice Yield by Rainfall Intensity and Water Harvesting Parameters

A regression with two or more explanatory variables is called a multiple regression. Rather than modeling the mean response as a straight line, as in simple regression, it is now modeled as a function of several explanatory variables (i.e. rice yield parameter as a function of both rain precipitation intensity and water harvesting or rainfall water management parameters).The function "*lm*" can be used to perform multiple linear regression in R and much of the syntax is the same as that used for fitting simple linear regression models. We estimated the production of rice by both rain precipitation intensity and water harvesting (management of rainfall water) parameters, developing a MLR model. The equation (E_2) of the present developed statistical model is reported as follow: (E_2) =*Y(estimate value of the rice production)=3.61 – 1.1*X_1 *(rain precipitation intensity) + 0.4*X_2 *(water harvesting)*. Assuming rain precipitation parameterasa constancy value (*-1.1*X_1= constancy) and increasing water harvesting parameter value (excellent management of rainfall water parameter or excellent monitoring of the water of the dam), we errand the augmentation of the production of rice, that correspond to an increase of Y variable (see equation E_2). This hypothesis suggested that a good management of rainfall water improving the water harvesting process, strongly increases the production of rice. However, an intensification of rain precipitation associated with a constancy or unceasing value of water harvesting parameter (bad management of rainfall water) ($0.4X_2 \sim 0$) will reduce the production of rice (see equation E_2). Together, the present analysis explains rice yield as a function of both rain precipitation intensity and water harvesting (rainfall water management), supporting that a good integration or board of the formers, may reasonably impact and improve the rice crop rate in the north area of Côte d'Ivoire. Next we calculated and represented (Fig. 5) the residual values estimated by the present MLR developed model, applying the followed formula;(E_3): ε = *real values of rice production – estimated value of rice production* (estimation of the production of rice by the above developed multiple linear regression model; equation E_2). This analysis showed that$\sum \varepsilon$ (sum of the residual values) $= -0.063 \cong 0$ (results of simulation analysis). Moreover, the calculated residual value of the developed MLR is in agreement with the elaborate residual graphic reported in figure 5. The present results suggest a stability of our predicting statistical model. At that point we can easily conclude that we are in presence of a MLR model with a constancy value as reported in equation (E_2).

Statistic of Estimated Parameters of the Developed Multiple Regression Linear (MLR) Model

Next we performed a simulation assay, achieving a statistical analysis of each estimated coefficient values of the above described multiple linear regression (MLR) reported in the equation E2. The statistic associated to each estimated coefficient has been computed applying the following function of the R statistical package: *print (summary (lm (formula = rice yield ~ rainfall + water harvesting)))*. The output file of this function associated to each estimated coefficient value ofthe developed MLR statistical model (MLR or E_2 =*Y (estimate value of the rice production) = 3.61 – 1.1*X_1 *(rain precipitation intensity) + 0.4*X_2 *(water harvesting)*),meanly exhibited a moderate statistical significance (p-value ≤ 0.1). However, while the statistic associated to the constancy value of our developed statistical model (3.61) exhibited a significant p-value (p-value= 0.01), the predictive values associated to rain precipitation intensity (rainfall) (p-value = 0.1) and water harvesting (management of rainfall water) (p-value= 0.08) parameters, displayed a moderate statistical significance. Considering as whole, these results suggested a reasonable stability of the developed LMR predicting rice production by rainfall and rainfall water management (water harvesting) parameters.

DISCUSSION

Wetlands are the important world's natural resources. They support the growth and development of wide varieties of natural vegetation and serve as breeding ground for many wildlife and fish species. They are also suitable for development for food production. The development of wetlands for agricultural production is very intensive and extensive in Asia. In Africa, there are large wetland areas but most of them are still unexploited or underutilized. Recently, in recognition of the limitations of upland production systems to provide sustainable food security to their populations, many Sub-Sahara African countries like Côte d'Ivoire have promoted the development of wetland areas for agricultural production. So far, although many other crops can be grown quite productively on wetland soils with adequate water management, most of wetland areas in the world have been developed for rice-based production systems. The wetland rice area, especially in Africa, has steadily increased during the period from 1975 to 1995 (Andriesse, W. *et al*, 1993). It is in this context that the dam of Natiokobadara has been built to improve by irrigation the rice production in the north area of Côte d'Ivoire. However in many rice growing area, global climate change combined with high rain intensity variation can have unfavorable effects on the yield of crop plants such as rice (Silué and Dago, 2014). In fact, without irrigation, rice production can be practiced only during the wet season and the rice cropping season is determined by the length and the pattern of rainfall. In areas which receive 1 200 mm of rainfall or more per year, the water supply is adequate for at least one rain fed wetland rice crop provided the rainfall is concentrated in one season and its distribution is reasonably uniform. Rainfall and its distribution, however, are very variable in both space and time as showed by Silué and Dago, (2014). Moreover, variability in the amount and distribution of rainfall are the most important factors affecting yield of rain fed wetland rice as supported by the present work. Therefore, here we developed a statistical multiple linear regression (MLR) to predict rice production thought rainfall intensity and water harvesting (rainfall water management) parameters. Our findings revealed a high variation in rice production and in rainfall water management (water harvesting) with respect to in rain precipitation from 2007 to 2013 in the north region of Côte d'Ivoire (Fig. 2 and 3). These results confirmed the observations outcome from the analysis of Silué and Dago, (2014). However, the principal component analysis (PCA)executed in the present study showed a potential good relationship between rainfall intensity and good management of rainfall water (water harvesting) predicting rice yield (Fig. 4).In the other word, the PCA analysis suggested that a good administration of the rainfall water (water harvesting)can contribute to the rice production improvement. Furthermore, the developed MLR (E_2) statistical model highlighted the relationship between the three analyzed parameters and showed that rice production is strongly associated to water harvesting (rainfall water management) parameter with respect to rainfall intensity parameter (Fig. 4). Then, the present developed MLR equation revealed that the improvement of rice production in the north of Côte d'Ivoire, did not exclusively depend on rainfall parameter (rain precipitation intensity).However, at present, about 40 percent of the total rice area is classified as rainfed (lowland or upland), while about3.5 million ha of rice-land are still being classified as deep-water or flood-prone (Maclean *et al.,* 2002).Variability in the amount and distribution of rainfall is the most important factor limiting yield of rainfed rice. In addition, we revealed that an unmoderated increase of rainfall intensity parameter could reduce the rice production. In others word the strong rainfall intensity due to the global climate change without any rigorous monitoring of rainfall water exhibited a negative effect on rice yield. Taking together, these results supported that the rice production in the north of Cote d'Ivoire is not directly link to the rainfall intensity parameters. However, this study revealed that the rain precipitation intensity in the north of Cote d'Ivoire associated to a good management of the rainfall water (improvement of water harvesting) through the structures like dam of Natiokobadarais an excellent way to guaranty the food security increasing rice yield in this part of the word.

Nevertheless, the present study partially suffers for the quality and/or size of analyzed data. To overcome this situation we performed and apply several simulation analysis based on to the present developed MLR statistical model displaying the stability of the former predicting rice production. In spite of all, the present developed multiple linear regression (LMR) model, resulted to be a reasonable and moderated (or stable)tool predicting rice yield through rain precipitation intensity and water harvesting (rainfall water management) parameters. In fact, the reasonable quality of the present developed multiple linear regression model has been supported by the significance statistical analysis of its computed estimate parameters and it good approximation predicting rice yield exhibiting a residual value around 0 ($\sum \varepsilon\text{-} = 0.063 \cong 0$) Efron, B., 1983, Efron, B., 1986).

CONCLUSION

The present study allowed the development of a multiple linear regression (MLR) model that is an essential statistical method for the analysis in agronomic field predicting crop yield through several environmental parameters. Here we provided a reasonable approach predicting efficiently rice yield in the north of Cote d'Ivoire by rainfall intensity and water harvesting (rainfall water management) parameters, showing that a good management of the water resource from rain precipitation (decent monitoring of the dam water by rainfall) meanly, contribute and improve the rice production and could help to food security in the word and in particular in the north of Côte d'Ivoire.

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